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COMPUTER NEEDS AND COMPUTER PROBLEMS IN DEVELOPING COUNTRIES

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ABSTRACT

This paper surveys the computer environment in a developing country. Levels of development are considered and the educational requirements of countries at various levels are discussed. Computer activities in India, Burma, Pakistan, Brazil and a United Nations sponsored educational center in Hungary are all described.

1. INTRODUCTION

The United Nations has developed many different indicators of the level of development of countries. In the computer area, four levels of activity corresponding to the country's use of computers have been defined [(2), p. 50]. These are (1) Initial, (2) Basic, (3) Operational, and (4) Advanced.

At the initial level there are no operational computers in the country. Most information about computers comes from salesmen.

At the basic level there is some understanding of computers in government operations. A few computer installations have been established, and there is some education and training in computer technology going on in the country.

At the operational level there is extensive understanding of computers, and there are numerous installations, some of which have very large machines. Centers for education and training in computer technology offer degree programs in computer or information science.

The advanced level involves pervasive use of computers with much government and administrative work being carried out by computers. There are quality educational programs offering a complete range of education and training. Professional societies have been established, and there is participation in national and international meetings and other activities. Many technologies have changed, or are in the process of being changed.

Computer education in developing countries may involve countries at any one of the above levels. For example, Brazil (see section 5e) is

clearly approaching the advanced category. At the same time they feel a need to become more self-sufficient in their graduate programs in computer science. Other countries may have no computers or a few recent installations. Here there is need for more training and advice at all levels, from operators to managers and from actual users to decision makers in government.

This last category, the decision makers, is particularly important. A developing country is characterized by a scarcity of resources. Foreign exchange is usually inadequate and that which is available must be spent for the most important items. Therefore, the people who make decisions about the allocation of resources must understand about computers. They must understand about staffing requirements and about application areas where the computer has the best chance of being successful at this initial stage of development. They must be able to realistically evaluate the statements made by computer salesman, and thus obtain the type of computer system best suited to their particular needs.

As shown later in this report, there is a real need for a means of teaching computer techniques to students of smaller universities and technical schools. For example, the school system in India is the second largest in the world (China is presumed to be first), but there are many universities, technical schools, and research institutes without ready access to computing. By using packet radio techniques low cost terminals (costing $3000 to $5000) could be placed at such schools. Not only would such terminals supply much needed computing capability at the smaller schools, but such communication would encourage contacts between computer users at different institutions, and thus encourage teachers to stay more up-to-date in their fields.

The central facility supporting these terminals need not be a large computer system. For example, there are mini-computers on the market, that support a language called BASIC, which would do the job. Such a computer with adequate disk storage would cost on the order of $100,000.

Some persons will say that there is no hope of establishing radio communication in a developing country. These opinions arise from restrictions on radio transmission usually established by the local military. However, recently, in just such an environment, a mineral resources project needed to do an aerial survey. The local counterparts working on the project said it could not be done -- that permission could not be obtained. The appropriate military official was contacted and approval was immediate -- the military people wanted the experience. Needless to say, a foreigner must operate with discretion under such circumstances, and it is most important to get all parties involved in the project.

2. APPROPRIATE COMPUTER ORIENTED CURRICULA

The curricula appropriate for an educational institution in a developed country may not be optimum for a developing country. For example, it may be important to teach "professional" subjects in order to prepare people to work in the field as soon as possible. At the same time, and as resources permit, it is important to develop university programs to provide more advanced training.

In fact, it is necessary to establish "pipe-lines", in both technical schools and universities, which will supply a continual stream of trained persons to take care of the future needs of the country. Until this is done the developing country will find itself spending foreign exchange to educate its computer people abroad. Besides taking valuable foreign exchange, this may cause "brain-drain" problems, and runs the risk of having the training not being ideally suited for the home environment. Another risk is that the candidate may elect not to take up the position for which the training was intended. Some countries require "bonding" to encourage the trainee to follow through, stipulating that a certain number of years must be spent on the job after training has been completed. On the other hand, careful planning is necessary to properly use the people who have been educated abroad so that their skills can be optimally utilized.

The United Nations report [(2), pp. 17-20] divides the educational requirements of a country into four categories:

(1) Education of decision-makers, managers, and computer systems analysts.

(2) Training of automatic data processing (ADP) managers and supervisors.

(3) Training of systems programmers and applications programmers.

(4) Training of engineers, technicians, and operators.

General managers and decision-makers need good orientation seminars which tell them realistically what computers can do for them and what the real costs are. Frequently, such seminars are provided by vendors and may be somewhat biased in their approach. Since the developing country usually has none or few computer experts it may be necessary to send some key people abroad for such training.

Computer systems analysts are concerned with the structure and mechanisms of organizations. Knowledge about economics, labor-management relations, operations research, and systems analysis are all important. Only a few developing countries will be able to be self-sufficient in these areas.

The ADP manager must understand computer systems and be able to evaluate proposed hardware-software configurations. He must, also, be able to adequately deal with employees, users, and vendors. After preliminary training, on-the-job experience for this person is important. Here the vendor of the computer system may offer help.

A systems programmer should be able to write special-purpose programs or adapt existing software systems to specific requirements of a particular computer center. He needs to be able to correct errors in systems programs. Most vendors have training programs in this area. Sometimes the vendor, as part of the installation contract, supplies an expert for peiods up to a year. Local personnel can serve an "apprentice-ship" with this expert.

Applications programmers must be experts in user languages (FORTRAN, COBOL, PL/I, etc.). Computer applications span such a broad spectrum that no one individual can be an expert in all areas. Therefore, the applications programmer must understand computing very well and be able to talk to the user (the expert in the specific field) and show him how to use the computer to solve his problems.

Operators can be trained on-the-job by concentrated short courses. Engineers and technicians require much more sophisticated training. If the vendor supplies maintenance, there may be no need for this category of training. This is an important factor for a developing country to consider.

How does a developing country start? If it is a first computer installation then assistance from the vendor is the easiest way to train operators and systems programmers. If there are other installations in the country then employees may be assigned to one of those for training.

Short concentrated courses are very valuable in the initial stages of developing computer usage. Such a course may last for two weeks and require the full time participation of the student. The main thrust will be the introduction of the student to a computer language (like FORTRAN). In one approach, during the first hour the student is shown a simple program which computes a table of squares and cubes. He is introduced to a keypunch, and he punches and tries to run this program. Immediately, he learns the inflexible aspects of computer languages--that you have to say it all and you have to say it right or the computer won't "understand" it. Also, the discipline of punching cards carefully is quickly learned.

Over the two week period some lectures in elementary numerical

analysis are given. The main purpose, however, is to remove any mysticism associated with computers, to teach the student that he must spell out computational procedures carefully, that the computer will do no more than the user is smart enough to tell it to do, that once a computational algorithm is checked out that it can be expected to perform the same way each time it is run, and that problems involving large amounts of data must have ways to be checked to verify that all procedures (both manual and computer) are performed properly, and that the data itself is correct.

In a developing country such courses will enable the identification of candidates for further training. Operators and potential systems and applications programmers may be recruited from the graduates of such classes.

The next step is a one year diploma course covering topics in information and computer science. Starting with a one-year diploma course, instead of immediately establishing majors or graduate programs in computer science, has several advantages. This procedure causes less impact on the traditional educational structure and yet provides formal recognition of the training to which the candidate has been exposed. Also, this scheme provides additions to the work force without too much delay. It is, in addition, a re-training mechanism for those who would like to change into the computer area from other disciplines or activities.

Students may be selected from graduates in mathematics, science, or engineering disciplines. The topics covered should include computational mathematics, the logical design of computer systems, computer languages and their translation, and operating systems. However, the programmer

really learns his trade by "doing". Thus, any formal education, such as described above, should be followed by an apprenticeship in an operating computer center under an experienced programmer.

For the first installation in a country, such apprenticeship training has to be obtained abroad or visiting experts must be brought in. Sending the trainee abroad is generally cheaper than bringing in the expert, because of the difference in salary levels. However, the visiting expert can train several people, and can assist in other ways (advising, planning curricula, and helping with difficult customer problems in the applications area). Also, the trainee suffers no cultural shock and is not attracted by foreign environments. In some cases a combination of the two methods may be desirable.

3. COMPUTATIONAL SERVICES

The first priority for computing in developing countries is in the educational area. In order for the country to rationally develop computer usage it needs a body of well trained professionals and programs which will supply the personnel needs as computer usage grows.

Historically, the early installations in educational institutions have been small batch processing systems. In recent years, small time sharing systems (costing approximately $100,000) have been available. However, in the developing country the first computer installation usually must serve all kinds of users. For example, the computer must do data processing as well as satisfy the educational requirements. Therefore, small batch systems have been almost universally used in initial installations. An exception is seen at the Indian Institute of Management at Ahmedabad, Inida (see section 5b).

Remote terminals on a larger computer have not been popular in developing countries because of communication difficulties. Frequently there is a shortage of trunk lines which makes it difficult to establish connections when desired. Alternate means of communication (such as packet radio) could make a real difference. This would allow small schools to have a terminal on which students could learn to compute.

4. PROBLEM AREAS

The initial establishment of computer activities involves a number of problems. Leadership is needed. Someone who is technically competent and strongly motivated is required. This person needs support in order to obtain the resources necessary to acquire staff and computer hardware. The success or failure of a computer installation depends very strongly upon finding this individual. Even if there is good foreign technical support, if there is no leadership among the nationals then the computer activity will have difficulty in succeeding. The author has personally been involved with a computer center in a developing country where the inability to cut through the "red tape" involved in acquiring a competent leader has limited the development of the computer activity. This is true in spite of more than adequate foreign financial support, foreign technical assistance, and adequately trained and experienced local staff.

With adequate leadership there is still the problem of how to acquire computer hardware. The cases referred to in section 5 had help from the United Nations, the Ford Foundation, and from the U. S. Agency for International Development. If outside help is not obtainable, then the country has to decide whether there is foreign exchange available for the purpose.

Customs procedures and duties are quite often designed to discourage the expenditure of foreign exchange. In some cases importation is forbidden and in others importation is discouraged by making the duty exhorbitant. Since computer components and supplies (like reels of magnetic tape) are often impossible to acquire locally in a developing country

this can be an extremely serious problem.

Then there is the problem of what hardware to buy. The computer salesmen will each "push" his own product, being careful not to mention any shortcomings it may have. Each will make glorious promises about future support in areas of programming, making manuals available, and obtaining applications programs. The buyer should check on how the vendor has performed at other installations that he has made under similar circumstances.

Perhaps of even more importance than the capability of the initial installation is the ability of the vendor to supply spare parts and provide adequate maintenance. Of course, it is most important that the country plan to make foreign exchange available for supporting the continued operation and growth of the computer center.

After a computer has been decided upon and installed, there are often serious technical problems that must be overcome. One of these is an adequate power supply. In developing countries power distribution systems may not have surplus capacity. Since they require imported equipment, most generally the existing systems minimally supply the current needs of the country. Regulation is poor, and feeder lines tend to be long, leading to excessive voltage drop. Heavy loading may cause excessive voltage fluctuations. In order to avoid burning out electric lights these variations are set to be on the low side.

Most power consumption in the developing country occurs with lights and electric motors. This means that even if the generating equipment was initally designed to maintain "standard" frequency, there

is little incentive to maintain it in adjustment. Since the need is not there, little effort is made to keep the generating equipment performing to the original standards. This means that in nearly all cases computer installations need voltage regulation. This is not too difficult a problem to solve as voltage regulators adequate for the job are easily available. Of course, expenditure of foreign exchange is probably required, which as noted earlier, carries its own set of problems.

If the frequency is not well controlled, then the regulator must be more elaborate (expensive), requiring more extensive equipment. This may require a motor generator system with controls for both frequency and voltage.

It was this type of system in which the alternator burned out in Rangoon (see section 5a). This caused a shutdown of the equipment for several weeks as the vendor would honor the guarantee, in the circumstances, only if the alternator was shipped back to England for rewiring. Later it was discovered that a heater had not been connected which was designed to keep the alternator warm enough so that it would not "sweat" when the system was not in use. Whether this was the real cause of failure is not actually known.

A particularly annoying practice in power companies in developing countries is that of turning off the power without notice. Since most of their users just start where they left off when the power comes on again, few complaints are generated. However, for a computer this is catastrophic for the job in process, and sometimes leads to loss of files in disk systems.

Telephone systems suffer for many of the same reasons as the power systems in a developing country. Since maximum coverage at minimum cost

is necessary, the quality of the lines for voice is marginal. Furthermore, the number of trunk lines from one exchange to another is minimal. The result is that the caller may get a busy signal, not because the destination phone is in use, but because all trunk lines between the two points are busy. This presents a very serious problem. As long as some kind of power is available, the voltage regulation and frequency control problems discussed above can be solved locally at the installation. Telephone communication problems are another matter. The level of computer use, by itself, would not justify expenditure for additional trunk lines or improved repeater amplifiers.

Supplies are another problem area. Not only are they often difficult to obtain, requiring foreign exchange and import permits, but they often need to be handled with extreme care. Punched cards are such an example. These must be carefully manufactured (so that the card reader will feed them one at a time), and they must be handled carefully in shipment. For instance, they must not be allowed to get wet. At the computer center they must be stored under controlled temperature and humidity. Few other products handled by shippers, warehouse people, etc., have to be as carefully handled.

5. CASE STUDIES

Case studies are considered of the following computer centers:

(a) The Universities' Computing Centre, Thamaing College Campus, Rangoon, Burma.

(b) Indian Institute of Management, Ahmedabad, India.

(c) Indian Institute of Technology, Kanpur, India.

(d) University of Islamabad, Islamabad, Pakistan.

(e) Three universities in Brazil.

(f) International Computer Education Centre, Budapest, Hungary.

(a) The Universities' Computing Centre Thamaing College Campus, Rangoon, Burma.

In 1970 UNESCO approached the University of California relative to a technical assistance project in Rangoon. The final contract was signed in February of 1973, and is to run for four years.

In contrast to the Computer Centers in many developing countries the initial Burmese staff leadership was excellent. The senior people had been trained in England or in the United States (at Stanford University). The director, Dr. Chit Swe, is a competent mathematician and has done an excellent job in setting up the center.

The computer (an ICL 1903), which was acquired with UNESCO funding, was installed in February of 1973 and operation has been very satisfactory, except for some motor generator troubles as noted in section 4.

The center is teaching various short courses and has established a diploma course in Computer Science. Besides the educational program there is extensive interest by various government activities in using the computer. A frightening task is the processing of the data for the Burmese census which was taken in 1973. (This is the first census since Burma became independent.)

It is much too early to measure the quality of this program. However, it is off to a good start. The quality of the director and his senior people promise high probability of success.

(b) Indian Institute of Management, Ahmedabad, India.

With help from the Ford Foundation, the Institute of Management acquired a Hewlett-Packard time-sharing computer. The system has both teletype terminals and CRT displays. The primary user language is BASIC[1]. (The small time-sharing computer system, using Hewlett-Packard or Digital Equipment Corporation hardware, is an ideal low-cost way of giving real computer experience to students.)

The leadership of the computer activity has been in the capable hands of J. G. Krishnayya. He has recruited staff and developed curricula with emphasis on management information systems.

They have a one-year diploma course in Informatics in Business and

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1. The original BASIC was developed at Dartmouth. It is similar to FORTRAN.

Government. The program includes courses on Business Systems, Operational Analysis, Management Information Systems, Computer Systems, Organizational Behavior, System Design, Logistics and Large System Analysis, and Computer-based Information Retrieval Systems.

To get some feel of a specific program in a developing country it is worthwhile to look at this program (see ref. 7). Mr. Krishnayya looks at the U. S. programs and says that they are developing "new cadres ... who will specialize in the system development function." He says management education is stressing decision making using existing accounting flows and the computer scientists are concerned with hardware/software to the exclusion of application utility and economic viability. Therefore, in the programs, there has been a push toward an interdisciplinary curriculum (see ref. 8) aimed at producing professionals who are "user-oriented, application-wise, ..., and conscious of changing hardware limits and system potentialities." On the other hand, he says, "European countries ... are reserving University type training for a very few specialists ... and provide graded work-a-day skills ... through a series of short courses ..." with certification as the person gains experience. With this background he proposes to offer a post-graduate course covering the following subjects:

(1) Organizational functions -- the process of running an enterprise.

(2) Operation analysis and modeling -- analytical and simulation tools useful in system design.

(3) Human and organizational behavior -- organizational structure, impact of information systems, the process of organizational change.

(4) Computer systems -- hardware/software systems and operating systems.

(5) Information analysis and system design -- data base concepts, system utility, managerial aspects.

(6) Information structures and files -- data management, security.

(7) Logistic and administrative systems -- accountability, audit trails, information retrieval.

(8) Real-time and on-line systems -- data communications, reservation systems.

(9) System design project.

c) Indian Institute of Technology, Kanpur, India.

The Indian Institute of Technology at Kanpur came into existence as a joint effort of the Government of India and nine American Universities[2] under contract to the U. S. Agency for International Development. This was one of five such Institutes. The Soviet Union assisted IIT/Bombay, West Germany--IIT/Madras, and the United Kingdom--IIT/Delhi. There had been earlier United Nations support for IIT/Kharagpur (near Calcutta).

The first installation at Kanpur was in 1963. The computer was an IBM 1620 with 40K digits of memory and three tape drives. Disks were not available when this system was ordered.

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2. California Institute of Technology
Carnegie-Mellon University
Case Western Reserve University
Massachusetts Institute of Technology
Ohio State University
Princeton University
Purdue University
University of California
University of Michigan

The computer was shipped from New York to Kanpur on a chartered DC7 (the plane had other scientific equipment on it). The plane landed in New Delhi for customs clearance only to discover that no manifest was available. The customs office "gave up" and said to take it to Kanpur and "let him know what was on the plane." The commercial airport at Kanpur would not handle a DC7. However, permission was obtained (after some negotiation) to use the military airport at Kanpur, and using borrowed military fork-lifts we transferred the equipment from the plane to trucks working between monsoon showers.

India collects road taxes at tax gates on the highways and there was one such gate between the airport and the Institute Campus. Rather than face the paper work involved in paying road taxes with USAID funds we borrowed an Indian Air Force truck to lead the convoy. We breezed through the tax gate with horns blowing before the tax inspector had figured out what was happening.

At the Institute we had to unload the computer into unfinished computer quarters. There was wet plaster on the walls and water standing on the floor. Getting the computer from the truck into the unfinished building with only man power available was a memorable experience.

Checking on crates, which we didn't dare open because of the environment, we decided that we were short one single phase frequency converter-regulator. The computer was 60 cycle equipment because of "Buy America" restrictions on USAID funds. India is 50 cycle. In an IBM 1620 the tape system is 3-phase and the CPU is single phase. A 3-phase converter was included, but no single phase. Several cables to New

York established that IBM was responsible. Within a week they located a single phase converter in Germany and air-freighted it to Delhi. But we had no import license! With the cooperation of the custom's officials, it was consigned as personal property to the administrative officer of the project.

With all these troubles we were still able to "power-up" the computer approximately two weeks after its arrival in Kanpur.

The point of this story is that the process of installing a computer in a developing country will frequently involve a variety of problems which would be of no consequence in a developed country. However, in a developing country any one of these may become a major problem.

The author and two other American computer experts[3] arrived on the campus the first of July of 1963. There was no Indian counterpart staff during that first year. However, operating staff was recruited and the Americans gave four two-week intensive courses open to people from any place in India.

These courses were so successful and well received, that since then there have been two to four such courses given each year, including the current one. These courses built up a cadre of users located at other academic institutions and in the government. At the same time numerical computation was taught to the local students.

Both in the short courses and in the IIT courses a "hands-on" philosophy was used. At the end of the first lecture the student was

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3. Professor Forman Acton and Dr. Irving Rabinowitz of Princeton University.

expected to punch up a FORTRAN program, debug, and run it.

In due course an IBM 7044 with disk and tapes was installed in the computer center. This system is now operating at near saturation.

During the ten years of the USA participation in the program there were five Americans helping in the computer area. Initially, the computer center was under Professor Kesavan. When he left India to go to the University of Waterloo in Canada, Dr. V. Rajaraman (E.E. degree at U.C. Berkeley) became director of the Computer Center. It was Dr. Rajaraman's vigorous technical leadership and administrative ability that helped make IIT/Kanpur the leading school in Computer Science in India. Certainly, the support of the first director, Dr. P. Kelkar, and the current director, Dr. M. Muthana, were also significant in making the computer program successful.

Another factor that should not be overlooked is the contribution of American visiting experts in other departments at Kanpur. These people were used to heavy use of computers in their home environments, so they encouraged their Indian counterparts to "become computer conscious."

The characteristics of the Kanpur program which contributed most in making it a success are the following:

(1) Most important, a first class Indian was found to lead the program. He not only developed a good service facility at the computer center, but he also established a good academic program, and a research program in computer science (with publications in such journals as the IEEE Transactions on Computers).

(2) There may have been a threshold effect, in that a large number

of American visitors, and the recruiting of many Indians from Western institutions, established (transplanted) a significant interest in computing.

Graduates of IIT/Kanpur are moving out to other institutions in India. For example, people from Kanpur are involved in setting up the regional computer center at IIT/Madras.

d) University of Islamabad
Islamabad, Pakistan

The Pakistan Commission on National Education proposed the creation of two new universities in 1959. One of these came into existence in 1964, and in 1971 construction was begun on new buildings on a new campus in Islamabad. Courses had been started in temporary quarters in Rawalpindi.

With help from the Ford Foundation the University of Islamabad acquired an IBM 360/44, which was installed in September of 1972. With visiting staff, supported by UNESCO, they started a series of intensive courses and a one-year diploma course is currently underway.

Pakistan is interesting because the relatively free economy has allowed institutions such as banks to establish major computer centers. The shortage of trained personnel has pushed up salary levels in the private sector, making it difficult for government institutions and universities to hire competent people. Thus, the most significant factor in the development of the computer activity at the University has been the lack of technically competent, agressive leadership.

The war with India and the retirement of the vice-chancellor have also served to delay the development of the program. Recently, a new vice-chancellor has been appointed, and she is taking decisive moves to improve the situation.

e) Three Universities in Brazil

There are three universities in Brazil which are particularly active in the Computer Science area. These are University of São Paolo, the Federal University of Rio de Janeiro, and Catholic University of Rio de Janeiro. Catholic University has been active for the longest time, having, in cooperation with IBM, established the Rio Data Center.

The main growth of computing in Brazil has occurred since 1967. The National Academy of Science report (3, page 76) reports there are 630 (in 1971) computer installations in Brazil with forty installations being located in thirty-one universities and research centers. In contrast to some other countries, training facilities and undergraduate level programs already exist. However, there is a serious need for a few doctorial level programs which can prepare people to teach in the other institutions. Most such training is currently done abroad at substantially extra cost to Brazil.

Recommendations for improving computer science education in Brazil (see ref. 4) include the following:

A. Each of the above Universities should plan for the continuous presence of foreign experts. These individuals should be recognized experts in their areas of specialization. They should spend

at least one year in Brazil. For each expert a local group should be identified who can work with him and sustain the activity after he leaves (4, page 1).

B. Summer Institutes should be held at the three Universities with participation from the whole computer community. These institutes should be used to stimulate research programs and to improve the quality of teaching in the other institutions (4, page 3).

C. Overseas training should be continued (4, page 4).

It is clear that computer usage and educational programs are well established in Brazil. For example, intensive courses on computing (mainly FORTRAN, BASIC, and COBOL) have been given to nearly 8000 students at just one of the universities mentioned (4, p. 4 of Part III).

f) International Computer Education Center

Budapest, Hungary

The Central Statistical Office of the Hungarian Government established a computer training center. This became a national training center and, in January 1973, became the International Computer Education Center with support from the United Nations Development Program.

The center has a dominant position in Hungary for training computer professionals. It also offers courses for computer technicians and general introductory (adult extension-type) courses.

The center also has an active publication program. It has produced most of the Hungarian Language technical literature to support the above

program (see 6, page 2).

The objectives of the UNDP support of the project include

A. The procurement of a centralized educational Computer facility and an educational computer network system.

B. To identify course requirements depending on needs of central and local governments.

C. To develop course curricula for all levels of education for

1) teachers of computer science

2) specialists in applied computer techniques

3) managers of computer facilities, and

4) non-specialist users of computers.

D. To perform research in educational methods.

E. To provide facilities for a limited number of qualified foreign students from developing countries.

F. To identify requirements for training of students from developing countries.

G. To conduct seminars and training for students from developing countries.

H. To organize and host international symposia in computer training.

The center will acquire in 1974 an IBM 370/145 and there will be provision for time-sharing and for remote terminals.

This activity is just coming into existence and it is much too early to assess its level of performance.

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